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CHARACTERIZATION OF BANANA FIBER/PISTACIA VERA SHELL CELLULOSE REINFORCED COMPOSITES

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ABSTRACT

The main objective of the work is to add value to the agricultural residue by fabricating a partially biodegradable composite that shows the best combination of properties. To achieve this, Pistacia Vera shells are opted and cellulose is extracted from it, of both nano and micro sized. Such cellulose is added as filler, to the long banana fibers reinforced polyester composite. Also, this novel material is characterized by testing tensile strength, flexural strength, impact strength and thermal conductivity. Peak Tensile strength for Pistacia Vera shell banana fiber/nanocellulose reinforced composite is found to be 19% higher than banana fiber based composite. Similarly, Flexural, Impact strength and Thermal conductivity results also exhibited good synergism.

Key words: nanocomposites, cellulose, pistacia, banana, acid hydrolysis.

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1. INTRODUCTION

Plants found their application in various fields of interest. Especially, in the area of material science, many researchers have done far-reaching research, which primarily focused on natural fiber reinforced composites. Their work mostly emphasized on fabrication and characterization of partially biodegradable composites [1]. On top, hybrid composites were also fabricated. The purpose of hybridization is to enhance the properties of composites such as strength, toughness and impact resistance [2, 3].

Low cost, high specific properties, low density, biodegradability, availability and non-abrasive nature are the principle concerns for opting natural fiber [4]. Natural fiber reinforced composites have high fiber content for equivalent performance, for which environmental impact is lowered. In spite of many benefits, there are also stressing disadvantages such as moisture absorption, incompatibility of fibers, low processing temperature and brittleness [5]. Significantly, hydrophilic nature of these fibers lowers mechanical properties due to moisture uptake. Several physical and chemical methods were investigated to improve fiber-matrix adhesion. When physical methods were sided by chemical

processes, chemical treatments as alkali, silane, acetylation, etc. showed improved adhesion and in turn improved mechanical properties. This effect was illustrated by treating elephant grass fibers [6] and rice straw [7] fibers with chemicals and its tensile strength was found to comparatively higher to untreated fibers. In spite of pros and cons, these novel composites are used for furniture parts, packing electrical appliances, the interior cladding of railway carriages, aircraft bodies, and construction [8].

Symington et al. studied the tensile strength of numerous natural fibers which include jute, kenaf, hemp, coir, sisal and flax. Taking the effect of moisture into consideration, jute fibers showed better mechanical properties [9]. Similarly, Wambua et al. studied sisal, hemp, coir, kenaf and jute fiber-reinforced polypropylene composites. Bringing these composites onto comparison platform, hemp composite showed higher tensile and flexural strengths while sisal composite showed higher impact strength [10]. Ratna Prasad et al. picked a different set of composites such as jowar, bamboo and sisal fiber reinforced polyester composite. Of these composites jowar, bamboo composites showed almost same tensile strength, which is relatively higher than sisal composite. Flexural strength of jowar composite was high when compared to the two other composites. In this way, extensive research had been carried out on the mechanical behavior of natural fiber reinforced composites. Whereas, natural fiber based composites thermal behavior is only bit cornered. Researchers such as Li et al., Idicula et al. worked on thermal properties of flax fiber based composite, sisal-banana hybrid composite. Conclusively, results showed that with an increase in fiber content there was a decrease in thermal conductivity [11]. Ramanaiah et al. investigated both mechanical and thermal properties of waste grass broom reinforced polyester composites. Results revealed that thermal conductivity increased with increase in temperature and decreased with fiber content. As well tensile and impact strengths increased with increase in fiber content. Most of the fibers were reinforced together in different combinations, to fabricate hybrid composites. Hybridization influenced certain physical parameters, for which mechanical properties were enhanced [12].

Endless efforts in any area are the basic need of research. So, researchers started working on the reinforcement of nanofibers. These nanofibers were extracted from plants in cellulose form. Instead of crushing the plant material directly to nano-sized, the reason for obtaining nanofiber in cellulose form is because it exhibits large surface to volume ratio, high tensile strength, high young's modulus and low coefficient of thermal expansion [13]. Cellulose is available in a wide variety of living species. Of which plant sources have abundance. To obtain most benefits out of the work, cellulose is extracted from the agricultural waste so that the magnitude of renewability is amplified. And cellulose is most often derived by acid hydrolysis. On the other hand, by controlling the parameters of acid hydrolysis, cellulose with a high degree of crystallinity can be obtained. With this promising nature the cellulose nanocomposites were used in paper making, food packing, gas barriers, coating additives and security papers [14].

Khan et al. investigated mechanical, barrier, thermal and structural properties of nanocrystalline cellulose reinforced chitosan composite. Due to the formation of percolating network and reliable filler matrix interaction the tensile modulus was improved by 87% at 5% weight fraction of cellulose [15]. Huq et al. developed alginate based nanocomposite films by incorporating cellulose and composites are characterized by mechanical, barrier and thermal properties. Tensile, thermal and barrier properties showed a significant increase in their values with cellulose reinforcement [16]. Haafiz et al. worked on microcrystalline cellulose instead of nano-sized. Polylactic acid composites filled with microcrystalline cellulose from oil palm biomass were fabricated, and their tensile strength decreased with increase in cellulose content due to poor dispersion [17]. Nanocellulose was hybridized with clay from which best combination of properties was observed [18]. Researchers also hybridized natural fibers with nano matter and resulting composites are characterized [19].

This work concentrates on fabrication, characterization and most importantly on the comparison of distinguishable polyester composites. As for novelty and to check the enhancement in properties, four sorts of composites are developed. Namely, nanocellulose based, microcellulose based, nanocellulose /

banana fiber based and microcellulose / banana based composite are developed. The cellulose utilized in the present work is extracted from Pistacia Vera shells powder by chemical treatments. Next to fabrication, the composites are characterized by testing Tensile Strength, Flexural Strength, Impact Strength and Thermal Conductivity. Later the results obtained for the four sorts of composites were compared with each other.

2. MATERIALS AND METHODS

2.1. Casting Materials and Chemicals

Ecmas Resin Private Limited supplied unsaturated polyester resin (ECMALON 4412), methyl ethyl ketone peroxide and cobalt naphthenate. The reagents such as NaOH, HCL, H_2O_2 are purchased from Anil Scientific Centre, Vijayawada.

2.2. Plant Materials

Durable, robust and rough banana fibers were supplied by Sakthi Pvt. Ltd, Chennai.

Pistacia vera shells are amply available agricultural residue. Therefore, cellulose for the present work is extracted from Pistacia Vera shells. Pistacia vera shells are crushed before treatment. The crushed Pistacia vera shells were washed with water and then allowed to dry for a day so that the moisture is removed.

2.3. Isolation of Cellulose Nanocrystals

30 grams of Pistacia vera shells powder is treated with NaOH for 20minutes at 70^0C. After every chemical treatment, the residue is washed with water so that unwanted chemical reactions are avoided. As the steps proceeds, the size of particles reduces. Hence, washing in successive steps is done by centrifugation. Later, a 60ml of 30% (w/v) H_2O_2 solution is added to the mixture and is stirred for 30minutes, and similar addition is done and stirred for another half hour. In the last step 100ml of 64 weight % of the H_2SO_4 solution is mixed with the residue at 70^0C and stirred for 45minutes. End pH should, however, be neutralized to seven to finish the extraction process [20].

2.4. Preparation of Composites

Composites are fabricated by initially mixing nanocellulose with polyester resin in a magnetic stirrer. Once the mixing is successfully done banana fibers are reinforced into the resin-cellulose mixture using hand layup technique and proper focus on the orientation is required as it is the long fiber reinforced nanocomposite. Samples poured into the molds are allowed to cure for 24 hours. After which the samples are carefully taken out and tested. ASTM standards are followed while fabricating the samples. A similar technique is used in the fabrication of other sorts of composites [21].

2.5. Tensile Strength

ASTM D-638 is the standard opted to test the tensile strength of the samples. Under this standard the samples are of 160mm x 12.5mm x 3mm in dimensions. With accuracy in achieving these dimensions, specimens having different weight fractions of cellulose nanofiber are prepared. Prior to testing, the specimens are glued with Aluminium strips which are meant for perfect gripping during testing. Finally, testing is done using Electronic Tensometer at a crosshead speed of 2mm/min.

2.6. Flexural Strength

Bend or flexural strength is tested either by 3- point bend or 4- point bend testing. 3- point and 4- point bending differ in the number of loading points while the supporting points are same. In this work, 3-point bend test is done as it eliminates the need to determine center point deflection. Equipment employed for this purpose is Electronic tensometer with flexural test fixtures. Samples are prepared

using ASTM D790M standard with 100mm x 25mm x 3mm dimensioning. Samples are tested with same crosshead feed as tensile strength.

2.7. Impact Strength

Biocomposites which do not undergo plastic deformation after the impact are fabricated as per ASTM D256M. For this standard, the sample is 63.5mm long, 12.7mm deep, 10mm wide. The notch of width 0.25 ±0.05 mm and included angle of 45° is a stress concentrated zone. 8 ±0.2 mm is the width remained under notch to stimulate the condition.

2.8. Thermal Conductivity

Guarded heat flow meter (Unitherm model-2022) is used to measure the thermal conductivity. ASTM E-1530 standards are followed in fabricating the samples. The samples are 50mm in diameter and 10mm in thickness. The thermal conductivity of samples is recorded by varying weight fraction and temperature.

3. RESULTS AND DISCUSSION

3.1. Tensile Strength

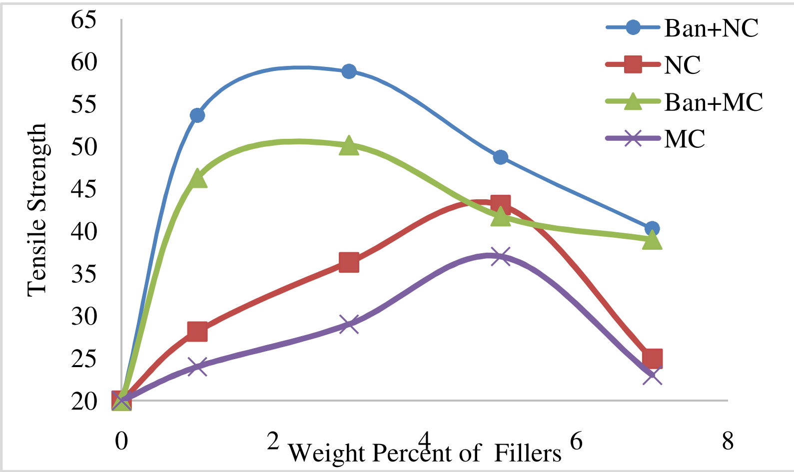

Figure 1 Variation of tensile strength with respect to weight percent of filler

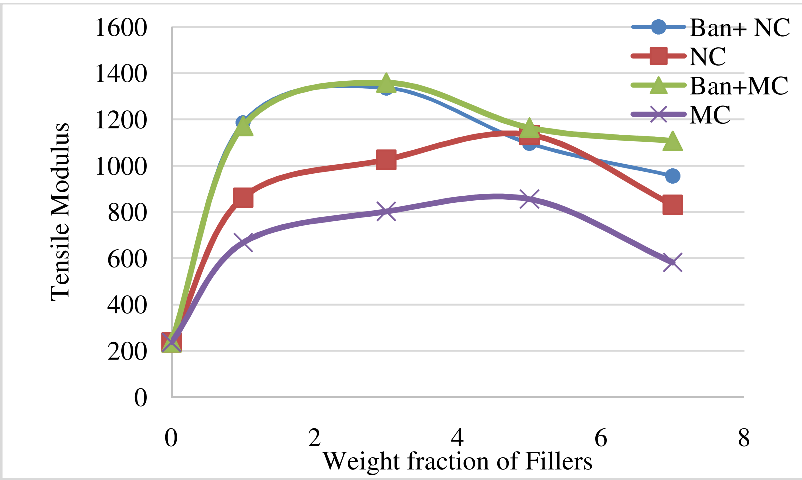

Figure 2 Variation of tensile modulus with respect to weight percent of filler

The basic test done to mechanically characterize a material is the tensile strength. In this work such fundamental property is tested for four differently combined materials. The purpose of combining materials is to check the possibility of amplifying tensile strength. Figure 1 shows the variation of the tensile strength of different composites with the weight percent of fillers, i.e., nanocellulose (NC), microcellulose (MC). However, 10 weight % banana fibers are kept constant in all banana fiber/nanocellulose composites (Ban+NC) and banana/microcellulose (Ban+MC) composites. And from the plot, it is observed that with an increase in weight percent of filler, tensile strength increased for all composites. But peak values in tensile strength are found for banana fibers/ nanocellulose reinforced composite. At 10 weight percent, banana fiber reinforced composites showed 45 MPa of tensile strength while resin showed 20MPa. This improvement in tensile strength is due to the transmission of applied stress to fibers. And this value is further improved by adding cellulose either in nano or microform. This enhancement implies that interface and adherence between banana fiber, cellulose and polyester resin are significantly improved. Especially, banana fiber/nanocellulose composites showed an improvement of 30 % over sole banana fiber reinforced composite. Tensile strength at 3 weight percent of fillers is 29, 36.3, 50.3, 58.8MPa for microcellulose, nanocellulose, banana fiber/nanocellulose, banana fiber/microcellulose based composites respectively. Lastly, the tensile modulus of different composites illustrated in figure 2, exhibited the same trend as tensile strength. Besides, banana fiber/nanocellulose and banana fiber/microcellulose showed almost same tensile modulus.

3.2. Flexural Strength

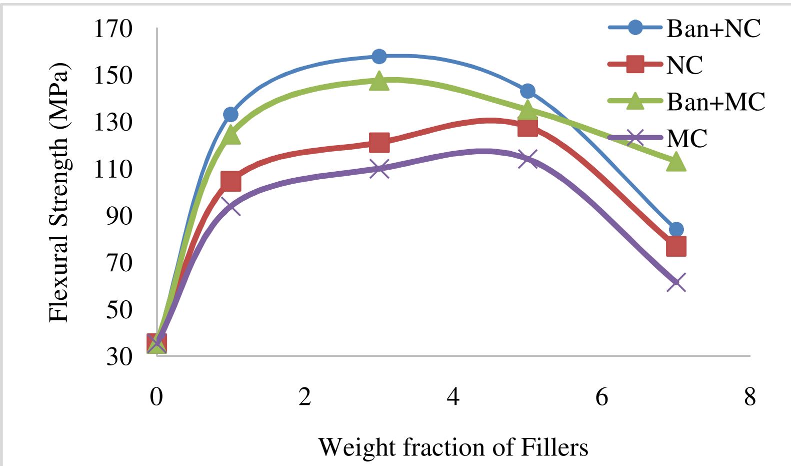

Figure 3 Variation of flexural strength with respect to weight percent of filler

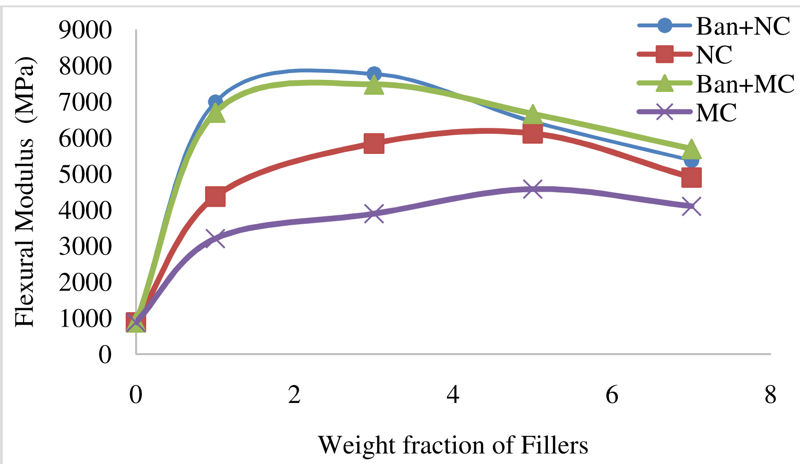

Figure 4 Variation of flexural modulus with respect to weight percent of filler

Figure 3 and Figure 4 shows the variation of flexural strength and flexural modulus with respect weight percent of filler. These results reveal that flexural strength and flexural modulus increased with increase in weight percent of filler. For flexural strength test, banana fiber based composites are fabricated with a constant weight fraction of banana fiber, i.e., 10% and only the filler weight fractions are varied. Banana fiber/nanocellulose composites showed peak value because free hydroxyl groups improved the interaction between fiber/ nanocellulose and matrix. Also, the load is initially taken by long fibers later cellulose. This statement is made because when the flexural strength of nanocellulose composites and banana fiber based composites is compared with banana fiber/nanocellulose composite, the banana fiber based composite showed such a close value to banana fiber/nanocellulose composite.

3.3. Impact Strength

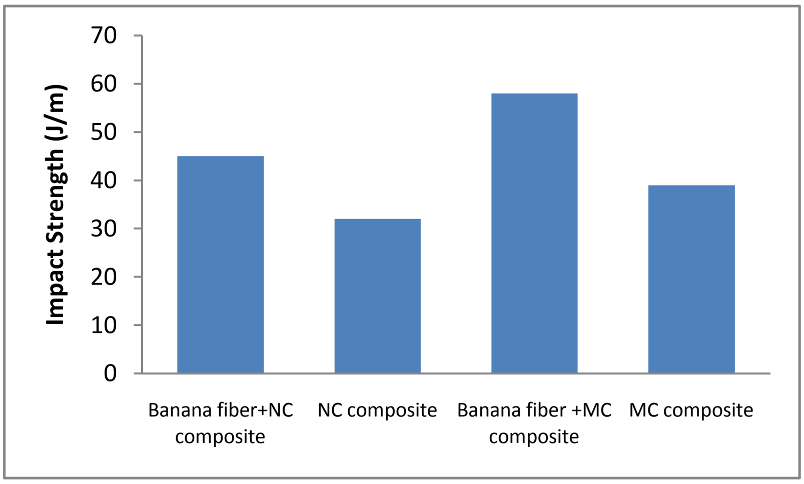

Figure 5 Comparison of impact strengths of different composites

The impact strength of different composites is presented in Figure 5. 58 J/m is the peak impact strength, and this value is shown by banana fiber/ microcellulose composite. This improvement in impact strength is due to the absorption of applied energy by cellulose microfibers. The effect may be further improved if the moisture content in fibers is nullified. Nevertheless, additions of bonding agents are vital factors to achieve impact strength.

3.4. Thermal Conductivity

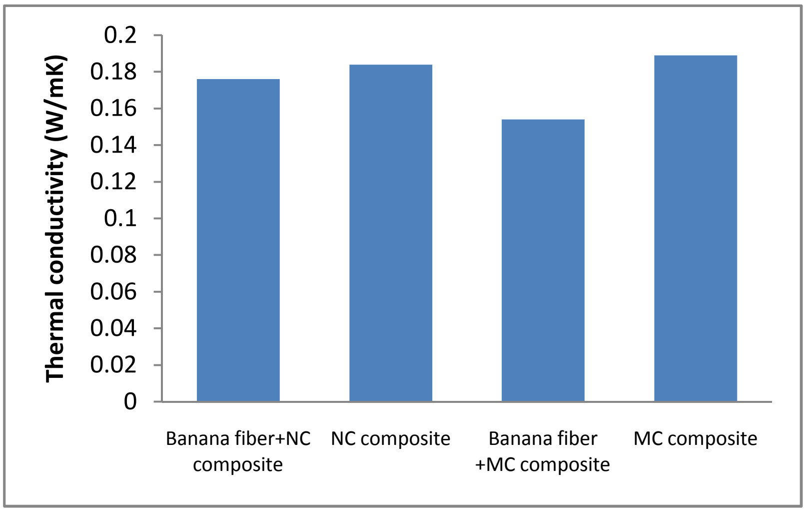

Figure 6 Comparison of thermal conductivities of different composites

It is clearly evident from the Figure 6 that nanocellulose composite and microcellulose composites showed only 0.005W/mK difference. Hence as fillers, cellulose showed almost same conductivity irrespective of their size when reinforced in a matrix. However, least conductivity is recorded by banana fiber/ microcellulose composite because this combination of hybridization can, even more, resist the thermal carriers.

4. CONCLUSION

In the present work,

- Characterisation of nanocellulose and microcellulose based polyester composites with and without fibers is done successfully.
- Tensile strength of banana fiber/nanocellulose composite showed peak value of all the composites at minimum weight percent of nanocellulose
- Flexural Strength and Tensile strength showed similar trends as the cause of improvement is same, i.e., sound inference and adherence
- When compared to other composites, at the same weight percent of filler impact strength of banana fiber/ microcellulose composite showed peak value.
- As a natural phenomenon plant material based composites exhibit low thermal conductivity of which least recorded is 0.154W/mK and this low conductivity value is shown by banana fiber/microcellulose composite

The results of the study indicate banana fiber/cellulose based composites are having promising mechanical properties and excellent insulating properties. Hence, these composites find their use at high temperature load bearing applications.

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